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INSTITUTE FOR DEFENSE ANALYSES

Inserting Commercial Technologies into Military Systems: Lessons from British Experience

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November 1997

Approved for public release; distribution unlimited.

IDA Document D-2104

Log: H 97-003716

This work was conducted under contract DASW01 94 C 0054, Task T-AW6-1466, for the Deputy Under Secretary of Defense for International and Commercial Programs. The publication of this IDA document does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that Agency.

PREFACE

This study was conducted under the IDA task entitled "Facilitation of the Insertion of Foreign Commercial Technologies into U.S. Military Systems and Lessons Learned from Foreign Case Studies." As the first step toward understanding and applying the experience of others in using commercial off-the-shelf technology to meet military requirements, this study concentrates on the United Kingdom (UK), which has a particularly robust and long-standing commercial insertion program.

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CONTENTS

SUMMARY

This paper examines robust and long-standing British experience using commercial off-the-shelf (COTS) technology to satisfy military requirements. It then develops a series of lessons upon which the new commercial insertion program of the U.S. Department of Defense may draw. These lessons are as follows:

- Cost drives defense acquisition managers to embrace COTS solutions to military requirements. Indeed, decreased budgets may no longer permit the military to take large risks entailed in developing militarily unique products. Thus, it is virtually impossible to avoid having some kind of COTS-based acquisition strategy in the future.
- Although the use of COTS technology is a powerful tool for stretching defense resources and for upgrading military capabilities, it is not a panacea. Using COTS technology often means accepting reduced functionality in the interest of affordability.
- COTS technology is applicable to a wide range of military problems but is not appropriate or adequate for all military requirements.
- Commercial products often require some modification for use in military systems.
- Commercial off-the-shelf solutions are more likely to be generated by requirements pull than technology push.
- COTS technology can be an important interim solution to a developmental problem.
- The use of COTS technology can reduce acquisition timelines.
- The nature of the military requirements validation and acquisition process can have a major effect on the chances of a COTS solution being adopted.
- How one handles the issue of standards in the requirements generation process is central to any COTS strategy.
- Flexibility in the acquisition process is essential if a COTS strategy is to succeed.
- Flexibility also leads to less control over the outcome of the acquisition process.

- Unless the military is willing to pay for adequate performance testing and parts characterization, it may not be able to predict system reliability well.
- The shelf-life of commercial parts and components may be too short under current military logistical practices.
- Introducing an extensive COTS-based acquisition program is a “long and painful” process.

I. INTRODUCTION

A. Background

The context for developing and fielding advanced technologies for U.S. military systems has changed in several significant respects since the end of the Cold War. For one thing, declining U.S. defense spending has dramatically slowed the pace of developing, perfecting, and incorporating new technologies into existing and developmental military systems. At the same time, small purchases of defense-specific components and poor commercial rates of return have persuaded a growing number of manufacturers to drop defense lines of business. Conversely, the commercial sector is exploding with innovative, affordable dual-use technologies that could become force multipliers for U.S. forces. Commercial market pressures and economies of scale also offer the Department of Defense (DoD) the chance to acquire state-of-the art technologies at less cost than would be incurred with the traditional development of military-specific systems.

Recognizing these developments, DoD has adopted a dual-use technology strategy that encourages defense programs to take advantage of existing domestic cost-conscious, market-driven commercial technology—commonly referred to as commercial-off-the-shelf, or COTS, technology. By leveraging the huge investments already made by private industry in leading edge process technologies, DoD hopes to reduce development, procurement, and maintenance costs. In the same vein, the Department has developed a prototype program called the Allied Commercial Technology Insertion Initiative to encourage the inclusion of foreign commercial technologies into U.S. military systems.

Many other countries, such as the United Kingdom, France, Israel, Sweden, and South Africa, already have robust, long-standing commercial insertion programs for military systems and components. Indeed, these countries are experienced practitioners in a process that the Department of Defense is just beginning to explore. The experiences of other nations therefore offer DoD a unique opportunity to identify and evaluate the successes and failures of others before embarking very far upon its own commercial insertion program.

B. Objectives

As the first step toward understanding and applying the experience of others, this study concentrates on the United Kingdom (UK), which has a particularly robust and

long-standing commercial insertion program. In doing so, we grapple with several issues: (1) What does the UK mean by COTS? (2) Why did the UK adopt a COTS strategy? (3) What advantages accrue to the British Ministry of Defense from using COTS? (4) What risks has the UK run in replacing defense-specific technologies with dual-use, off-the-shelf ones? (5) How did the Ministry of Defense structure and implement its commercial insertion program? (6) How widely applicable are COTS solutions to defense requirements? (7) How readily accepted is the COTS concept within the British Ministry of Defense and among its suppliers? We assess these issues with an eye toward lessons that DoD might apply to its fledgling commercial insertion program.

C. Definitions

Before going any further, it is important to note that British and American definitions of "COTS" are generally similar but different some important ways. Both agree that commercial off-the-shelf items consist of products and services that are either now, or soon to be, available in the commercial marketplace to satisfy government requirements. The British definition of COTS, however, also includes commercial products that have been modified in some way to meet military requirements. The U.S. Department of Defense, by contrast, has a special category called "non-developmental items" for commercial products that require only minor modifications or modifications of the type customarily available in the commercial marketplace to meet military requirements. Thus, when the British use the term "COTS" they include both what the U.S. Department of Defense calls COTS *and* non-developmental items. For the sake of simplicity, this study has adopted the more inclusive British convention rather than struggle with the problem of decoupling the two concepts in the interview process.

D. Approach

The study employs a number of different but complementary techniques in addressing the issues just raised. First, we draw on our extensive knowledge of the interworkings of the international defense and dual-use markets to understand emerging opportunities and pressures that are driving nations like the United Kingdom increasingly to insert commercial technologies into military systems. We also surveyed trade journal literature and commercial brochures to identify the British programs that employ commercially derived, dual-use technologies; the kinds of technologies that have been inserted; and the mix of domestic and international commercial products. Next, we

interviewed approximately 35 people (about evenly split between senior British Ministry of Defense personnel and business executives) involved in planning and executing the UK's commercial insertion projects.

After completing the examination of British experience, we assessed the implications of that experience for DoD's emerging dual-use technology insertion program. The result is a set of lessons learned that addresses the questions raised in the objectives section of this introduction.

II. THE BRITISH CASE

A. Overview

The British COTS program was born of necessity, nurtured by opportunity, and sustained by bureaucratic flexibility within the Ministry of Defense (MoD). Today, COTS technology is a major factor in most British military procurement decisions. However, coming to terms with the extensive use of COTS technology has been, in the words of one interviewee, a "long and painful conversion." Indeed, tension still remains as the British MoD struggles to draw the line indicating where COTS technology is an acceptable substitute and where militarily unique technologies are essential. Others still resist full implementation of a COTS strategy for bureaucratic, operational, and financial reasons despite official endorsements of COTS technology by the Ministry of Defense.

Virtually everyone agrees that COTS is not a panacea. At the same time, there is a consensus among government and industry people that COTS is here to stay because such off-the-shelf technologies offer the best hope for modernizing British military capabilities with leading edge technologies and because the MoD has no other choice for a variety of reasons which will be discussed later.

B. Why COTS?

Serious British interest in COTS solutions to military problems began during the Falklands crisis of 1982. There the MoD, strapped for funds and short of time, used commercial transport ships as supplemental "aircraft carriers" to launch Harrier vertical take-off fighters against the Argentineans. This stopgap measure demonstrated the robustness, flexibility, and cost-effectiveness of commercial solutions to military requirements. Indeed, this one seminal experience led to a new openness within the British MoD to consider COTS products where they proved cost-effective and militarily capable.

The movement toward COTS solutions to military requirements gained speed as post-Cold War British defense budgets shrank precipitously. Thus, cost became the primary incentive for the MoD to pursue COTS options.

Smaller defense budgets meant that the MoD procured fewer systems, thereby raising per unit costs significantly. Conversely, exploiting commercial off-the-shelf items allowed the MoD to take advantage of the economies of scale of the larger, dual-use market. Rates of return for suppliers consequently declined, and military customers became less attractive to many potential suppliers. In fact, many suppliers left the defense market altogether. With less than a one percent share of many high tech markets, the MoD found it no longer had any leverage with potential suppliers.

At the same time, fewer funds meant that the MoD could no longer take large risks on developing militarily unique products, even if it could find a manufacturer willing to build them. Resources became so scarce that each MoD project had to have a high probability of success from the very beginning or it was not undertaken. Again, COTS products seemed to be the answer since they exploited proven technology.

The consequences of fiscal constraints and a desire to shorten the project timelines are well illustrated by the case of 5 x 5 inch and 6 x 6 inch Active Matrix Liquid Crystal Display (AMLCD) displays for the Fast Jet Fighter upgrade program. The MoD estimated that it needed no more than 50 to 100 AMLCD units—a number too small to induce any manufacturer to build a dedicated military production line. Even if the MoD could have found a willing supplier of militarily unique tactical displays, the cost would have been prohibitive. Thus, the MoD turned to commercial suppliers.

One potential supplier offered to modify an existing, commercial AMLCD display so that it would function in direct sunlight. This was done by increasing the density of the back lighting and by sealing the entire unit between two pieces of military specification glass within a metal frame to keep the unit within military tolerances. The company also developed a new cooling system to keep the unit within temperature ranges acceptable for commercial systems. Finally, the top panel was coated to reduced reflectivity and glare. All of this developmental work was funded by internal company R&D money.

COTS products have also become an important "gap filler" when military-specific components do not meet original expectations or when their development takes longer than expected. A case in point is a recent UK frigate project whose military navigational radar was deemed inadequate. As a result, these frigates went to sea with a substitute

COTS radar until the problems with the military system could be resolved. In this case, the COTS radar had sufficient plotting and tracking capability for minimal military needs. Consequently, MoD bought these radars plus 5 years of contract support to reduce maintenance overhead costs.

Commercial purchases additionally offer a way of more quickly getting capabilities into the field. Commercial product cycles are short, often no more than 18 months at the outside, whereas traditional military product cycles can run more than a decade. The use of COTS technology also offers the possibility of reducing time from project start-up to the fielding of new capabilities because, in some areas, commercial leading edge technologies are already well ahead of comparable existing military technologies.

Cost considerations have also driven the MoD to outsource more and more generic military functions to private contractors. The British Army Logistics Agency, for example, has contracted out most of the logistics planning, transportation, and support efforts to private firms. Similarly, the Royal Air Force is using contractors for the EuroFighter's Logistics Support System. Likewise, the Royal Navy employs support contractors to keep pace with information technologies as well as to begin integrating its command support system.

While recognizing the need to maintain a core capability for strategic transport, the Ministry of Defense relies extensively on civil assets to meet its sealift requirements. The Ministry, for example, chartered 91 merchant ships in 1995. Also in May of 1995, the Ministry chartered a British Offshore Support Vessel to locate and map the wreckage of a Royal Air Force Nimrod surveillance aircraft that had ditched in approximately 50 meters of water. More recently, the Ministry of Defense chartered the Ukrainian flagged roll-on/roll-off vessel (*Yuriy Maksaryo*) to move 31 Challenger tanks, 550 armored vehicles, ammunition, packed fuel, general stores, and assorted other vehicles from Britain to Croatia in support of British military forces operating in Bosnia during Operation RESOLUTE.

The Ministry of Defense also draws heavily on the commercial market to augment the Royal Air Force's Air Transport Forces in meeting operational, training, and administrative support requirements. Chartered aircraft, procured by competitive bid, serve a variety of airlift functions such as routine air trooping to Germany and special operations support in places like Angola and the former Yugoslavia. Similarly, the Ministry procured discounted civilian airline seats from over 40 British and overseas

airlines between 1994 and 1995. In 1994–95, the Ministry spent 16.5 million pounds to charter commercial airlift support and another 41.5 million pounds for seats on civilian aircraft.

The British Ministry of Defense also makes extensive use of commercial rail assets to move both people and materiel. Indeed, commercial rail is now the preferred method for the bulk movement of ammunition and explosives within Britain. This success has led Ministry planners to identify ways of moving heavy armored vehicles between barracks and training areas via commercial rail. The military also uses containerized rail capabilities to move vehicles and equipment to the European continent via the newly opened Channel Tunnel.

The British military moves resources by road in its own trucks when operationally necessary. Where practical, however, the military makes substantial use of civilian vehicles to move freight by road. The Ministry of Defense believes that this arrangement is the most cost-effective use of its own road transportation assets and procurement funds. The Ministry does not believe that this arrangement has diminished its core capabilities to meet its peacetime and crisis responsibilities.

The Ministry of Defense is also considering the possibility of adopting the commercial practice of leasing equipment as a way of stretching scarce annual defense appropriations. Under the Private Finance Initiative, the Ministry of Defense hopes to generate off-budget financing of some systems which the Ministry, in turn, would lease back from the private owners for some specified period of time. Additionally, the MoD hopes that private financing will encourage prime contractors to search for additional markets/customers leading to third-party revenues. By doing so, the Ministry would avoid the large up-front costs of fully funding procurement as well as secure the economic benefits of the larger production runs generated by third-party sales/leases.

For example, there is considerable discussion about the possibility of the Ministry of Defense leasing Rolls Royce military aircraft engines. As with standard commercial leases, Rolls Royce would be responsible for maintaining the engines. It is believed that this arrangement would induce the vendor to pay greater attention to life-cycle costs and maintenance issues in order to keep overall lease costs low and profits high.

C. Impact of the Requirements Validation and Acquisition Process

The nature of the British military requirements validation and acquisition process has a powerful impact on the chances of a COTS solution being adopted. In part, this is

because the acquisition process forces decision makers to confront the COTS alternative directly. (See Figure 1 for an overview of the entire process.)

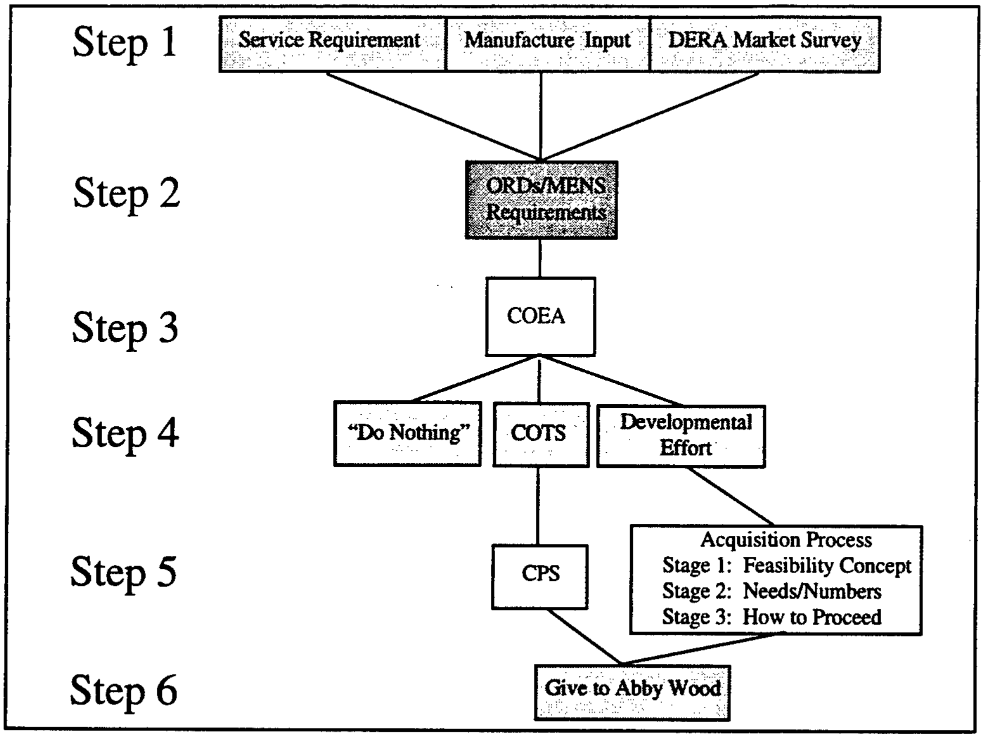

Figure 1. MoD's Procurement Process Steps

The current Ministry of Defense approach to acquisition stems from fundamental changes that occurred in MoD procurement policy in 1985. These changes were so profound that one interviewee described them as "a major shift in the [acquisition] culture." Up until this point, the MoD was the designer, producer, and systems integrator for all of its weapons systems. Since 1985, the Ministry has divested itself of industrial holdings and has become an intelligent customer emphasizing broad themes like functionality, cost, and mission capability. Concomitantly, the MoD has increasingly relied on contractors to design, integrate, and produce military end-items.

Generally, the process for identifying and validating requirements in the UK appears very similar to corresponding practices in the United States. Each British Service receives inputs directly from operational personnel. These requirements are then validated by the central staff and incorporated into requirements documents closely resembling U.S Operational Requirement Documents (ORDs) and Mission Essential Needs Statements (MENS). As in the United States, these statements of operational needs are used by the development community to identify militarily viable technical solutions.

Next, the MoD conducts combined operational effectiveness and investment appraisal (COEIA) in order to squeeze as much out of every defense pound as it can. These assessments identify and evaluate opportunity costs as well as risk factors. The result is that risk/performance/cost trade-offs are taken seriously within the procurement process.

At this point, evaluators face one of three choices regarding a requirement: (1) do nothing, (2) adopt a COTS solution, or (3) develop a militarily unique solution. In theory, evaluators are free to choose any of the three approaches just outlined. But in practice, severe budgetary limitations make it difficult to develop military-specific solutions very often. Therefore the real choice is usually between doing nothing or seeking a COTS alternative.

Regardless of their ultimate choice, evaluators have to consider the possibility of using COTS for virtually every requirement (except those dealing with nuclear weapons and nuclear delivery vehicles) as part of the formal acquisition process. The structure of the process, therefore, pushes the outcome towards COTS solutions.

In those cases where the COTS option is selected, the MoD drafts a Cardinal Point Specification. This document articulates functional performance specifications that are oriented toward meeting operational requirements without setting forth exacting technical specifications. When technical specifications are unavoidable, the MoD turns first to commercial specifications, followed by international specifications, NATO specifications, and then UK national specifications. Exacting military specifications are employed only as a last resort. In doing so, MoD has adopted a practice that is consonant with the market motivations of potential suppliers as well as the specifications to which available commercial off-the-shelf technology has been designed. The Cardinal Point Specification approach also encourages designers to use an open architecture which, in turn, also works in favor of adopting commercial solutions.

The change from technical to functional specifications and the decline of defense budgets have changed the outlook of Program Executives as well. They are no longer solely concerned with making sure products meet exacting technical standards. Instead, they now seek the best functional solution within budgetary limits, often accepting reduced functionality in the interest of affordability.

The combined effect of the acquisition process and MoD's attempts to harmonize COTS procurements with commercial markets is a cost containment strategy resembling a commercial investment portfolio scheme. For each procurement, risks are measured,

impacts estimated, and risk management plans produced. Tender offers reflect a consideration of risks identified. Later, a post-contract risk assessment calibrates the accuracy of the original estimate and draws lessons which will benefit future assessments. This strategy also helps avoid situations in which a low bid contract is so risky that it leads to significant, unexpected downstream costs. MoD can now hedge its bets by leaving open the option to disqualify an awardee based upon new information gathered during the execution of the contract. Interviewees believe that this process would avoid a situation that occurred several years ago wherein refurbishing Tornado aircraft resulted in damaged airframes—something that was not detected until 15 aircraft had already been modified.

Overall, MoD acquisition practices make it easier to accommodate the use of COTS technology in military systems while at the same time making it more attractive for commercial suppliers to provide such technology. The movement away from detailed technical specifications (especially military-specific ones) to performance-based Cardinal Point Specifications has also increased the acceptability of British weapon system designs in the export market. Reliance on commercial standards also makes it is easier for users to modify products in the field. These are important considerations since approximately one-third of all British defense production is exported.

D. Flexibility and Informality Within the Acquisition Process

The British acquisition process is built more on tradition and custom than on statute. Indeed, the entire body of British procurement regulations is contained in but a few Acts of Parliament and a few European Union regulations. Thus, unlike in the United States, it is very difficult to mount legal challenges to British government decisions. Also, unlike in the United States, the British defense industrial base is relatively small. These two features have encouraged a very close relationship to develop over the years between government entities and industry. In some cases, like the Defense Evaluation and Research Agency, for example, it is hard to tell whether an entity is public or private. The resulting flexibility affords the UK many advantages that are not currently possible within the U.S. system. Among them are a much closer dialog between government and industry and greater latitude to increase the scope of contracts without recompetition.

More specifically, budget limitations make it difficult to get prototyping authority from MoD; but, once such authority is granted, there is no formal requirement to recompete. Rather, the MoD does a "bake-off" to select a firm (or firms) to carry out the

prototyping, but it generally is not required to revisit the award. As a result, it is possible to begin weapons procurements without ever declaring a full operational capability. Firms are also already aware of MoD intentions when a program is initiated and are therefore able to craft their initial tender offers to conform more closely to MoD needs than is currently possible under the U.S. acquisition system.

In the same vein, the Ministry of Defense also has an exchange program with industry whereby civil servants are loaned to industry on a temporary basis and industry people are seconded to the Ministry for a short time in order to promote "a clear understanding of how each is organized, how corporate decisions are taken, and the nature of the problems they both face in an increasingly competitive world."[1] The Ministry believes that this program "allows civil servants to experience the pressures of a commercial environment at a time when the *MOD is becoming more commercially oriented* [emphasis added]."[2] This is important because "the MOD has long been aware of the need for its staff to gain first-hand experience in a commercial environment and in the value that such experience brings to the Department."[3] A Ministry brochure says, "We are engaged in fundamental change in the way we operate involving the application of the best management practice to all our activities" at a time when the Ministry must operate "within strict cost controls."[4] Industry, for its part, gains in that its people develop a better understanding of the problems the Ministry faces, how it works, and the constraints under which it operates. The result of this process is a much closer relationship between industry and the Ministry—one that promotes a free flow of ideas across government/industry boundaries, increases the Ministry's awareness of relevant commercial technologies (and at an earlier stage in the requirements and acquisition process), and offers industry a much better understanding of the Ministry's potential requirements for COTS technology.

As already mentioned, the Defense Evaluation and Research Agency is blurring the lines between government and industry. As the complete research, development, testing, and evaluation organization for the MoD, the Agency is responsible both for helping to define requirements and for providing technical support for procurement

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1 Ministry of Defense, Interchange with Industry Team brochure, p. 1.

2 Ibid., p.2.

3 Ibid.

4 Ibid., p.1.

actions. Additionally, this Agency is responsible for evaluating competitive bids on MoD contracts.

Although it is a government organization, the Defense Evaluation and Research Agency is generally viewed as a service provider and, as such, is expected to "earn" its government money. Additionally, the Agency is permitted/encouraged to aggressively pursue commercial contract work to supplement its income. (Up to 100 million pounds of private work goes to the Defense Evaluation and Research Agency each year.)

The Ministry of Defense's COTS program benefits from the Defense Evaluation and Research Agency's dual, public/private persona in several ways. Its dual mode of operations allows the Agency to maintain a continuous dialog with industry, thereby keeping abreast of technological changes. This is an especially important advantage in technologically dynamic sectors like software engineering where state-of-the-art technology is evolving very quickly. The Agency's detailed awareness of the commercial technology base permits it to identify potentially relevant COTS technologies early in the MoD's requirement definition process. This, in turn, increases the likelihood of COTS solutions being adopted later in the acquisition process.

The Defense Evaluation and Research Agency's role in the incorporation of commercial flat panel displays into military systems is a good example of how it uses its unique position to MoD's advantage in the COTS arena. According to Agency officials, their original strategy was to push this military-developed technology out into the private sector to reduce prices through the economies of scale that would result from commercial sales. It was anticipated that, as prices fell, the MoD would be able to find vendors willing to custom design military flat panel displays at lower and lower cost. Ironically, due to the success of flat panel technology in the private sector, commercial firms came to regard military-specific business as more trouble than it was worth.

Recognizing the failure of its original strategy with respect to flat panel displays, the Agency identified militarily viable commercial opportunities for MoD, engaged in some advanced technology demonstrations, and undertook a small amount of fresh technology development. In the end, modified commercial flat panel displays were incorporated into British military aircraft as described earlier in this paper.

Despite such successes, the dual public/private character of the Defense Evaluation and Research Agency poses some serious problems as well. For one thing, the Agency has had to go to great lengths to ensure that all potential contractors are handled equitably and that all bidders receive equal access and support in the acquisition

process. Despite its best efforts in that regard, many in Britain are still alarmed about the potential conflicts of interest inherent in the Defense Evaluation and Research Agency position as the nexus between government and industry, especially given its influential role in acquisition decisions despite its contract work with private industry.

E. Continuing Problems and Unresolved Issues

The movement toward greater reliance on COTS for military systems has been a rocky road within the British Ministry of Defense. The process has raised a number of troublesome issues and difficult trade-offs for defense decision makers, designers, and operators. In short, there is a downside to using COTS technology as well as an upside.

One interviewee emphasized that a successful COTS program is largely a matter of philosophy—something that implies getting people to accept the new ways of doing business. Unfortunately, there are still some serious pockets of resistance to implementing a more robust COTS strategy. Some naysayers are simply clinging tenaciously to old ways of thinking, while the rest are defending bureaucratic interests; e.g., defense manufacturers fear that COTS undercuts their market niche.

Some industry representatives, for instance, indicated that, in the past, COTS products were seen as a nuisance whenever they were introduced into the design process. That attitude is changing as engineers and designers become more familiar (and hence comfortable) with COTS items. The issue is largely a cultural one of how to coax engineers to stop writing their own specifications and, instead, develop designs based upon existing commercial products. One approach is to develop ties with particular vendors so that weapons designers can become more familiar with a particular family of products.

Thorough knowledge of the technology is essential to using COTS. Without such knowledge, it is possible to select and employ a commercial product that lacks some features required for military applications or that cannot deliver in harsher military operating environments.

Even when the technical characteristics of a COTS alternative are well understood, it is not always clear how to use COTS technology to the best advantage in military systems. This problem can be overcome to some extent by considering COTS alternatives very early in the design process. According to one industry source, military customers are often "naive" about the way COTS products might be used. In such cases, the burden falls on the overall commercial system integrator to find solutions and to

educate the military customer in the appropriate use and trade-offs involved in opting for COTS solutions to military requirements.

In its search for appropriate COTS solutions to military requirements, the British MoD looks at the international marketplace as well. Indeed, one official claimed that "foreign firms are always included" when considering possible COTS solutions. The Ministry also maintains regular liaisons with Hanscom and Tinker Air Force Base personnel in the United States as well as with the French aerospace community. The British MoD does this for two reasons: (1) to uncover potential COTS options and (2) to avoid being double charged for modifications already financed by another nation.

Despite interest in foreign commercial technologies, there are barriers to their adoption. One important barrier is political. That is, British politicians are reluctant to procure foreign COTS products, preferring instead to produce something in Britain. There is also a problem, especially in this age of offset production, of determining what constitutes "foreign" production; i.e., does manufacture in Britain of an item under license to a U.S. company or by a U.S. subsidiary count as domestic or foreign production. Regardless of the answer to this question, there was an undertone in the interviews that the use of foreign COTS products is much more difficult to accomplish than a description of the process would suggest.

The Cardinal Point Specification approach of defining requirements in functional performance terms rather than technical ones is generally considered a good idea in theory. However, some critics point out that the "reality is not as good." Sometimes commercial components that will not operate in more demanding military environments are selected. Part of this issue deals with what to do when military specifications and standards are no longer enforced, but commercial standards are not yet fully characterized for military environments? (This issue is currently being addressed by the Society of British Aerospace Companies which has not yet arrived at a solution.)

Initial good intentions and functional descriptions of the Cardinal Point Specifications, however, frequently fall victim to a tendency to change the details as the project progresses, hence undoing the original intent of having a stable, performance-based solution. Some projects are better than others in this respect. It seems there is always an urge by some government officials to "tune" the project as it progresses, e.g., "meddling" with requirements, specifications, and research agendas. Some cynics, for example, charge that government people deliberately issue change orders as a way of

justifying their continued existence and budgets. When this happens, the project moves farther and farther away from a pure COTS solution.

Another difficulty is that the Ministry of Defense cannot control changes in commercial technologies and practices over time, even though they may have serious negative implications for weapons systems employing COTS. There is, for example, no way of preventing industry from changing its product lines so that they no longer support (or are even compatible with) the military applications designed around them.

A good example of this problem is the Motorola 68020 chip and the ADA assembly code that was written to take advantage of the mask 1 version of that chip. Over time, Motorola changed the mask four times to save money in the manufacturing process without notifying either industry or the Ministry of Defense. The changes to mask versions 2–5 did not affect commercial software operations. They were, however, incompatible with the military code written to take maximum advantage of the unique features of the initial mask. Thus, France was forced to purchase mask 1 for the Motorola 68020 chip and to continue producing the outmoded version in order to meet its continuing military needs. Facing the same dilemma as the French, the UK was then forced to purchase replacements from the French and/or to stockpile the number of chips it estimated would be needed in the future.

Some COTS items can also lead to long-term reliability and maintainability problems for the Ministry of Defense. The commercial design process, for instance, may lead firms to adopt economically efficient solutions that are not robust enough for military purposes. Minimizing track widths on circuit boards, for instance, may lead to the formation of "whiskers," thereby leading to short circuits. Such faults are difficult if not impossible to track. Ultimately they reduce system reliability.

Another example of the kinds of reliability problems that can spring from using commercial items is illustrated by 486 chips which are packaged in plastic. Plastic acts like a sponge and absorbs water over time. As a result, plastic packaging may corrode and damage its metal and silicon components. Plastic packaging faces other environmental unknowns since it is not being tested at present for the effects of vibration, salt, fog, heat, and so forth.

Since commercial manufacturers do not always characterize their parts under a wide range of military environments, it is often impossible to predict whether a system will work when needed. Redundancy will help relieve this problem but will not eliminate it completely. Although it is possible to build in redundancy by using different

commercial products, there is no guarantee that the products will not fail simultaneously, especially if all were purchased from one manufacturer who presumably would use the same standards and environmental tolerances across multiple product lines. A better strategy would be to purchase components from different batches over time or from different suppliers and then to reexamine their behavior on a periodic basis. Indeed, the military may have to pay a premium to get adequate testing and characterization if it wants reliability.

Inadequate shelf life of COTS products may be another problem for the military. The Intel 486 chip, for example, is designed to work for only 5 years. The military's need for these chips, however, may last well beyond 5 years (e.g., some military systems are expected to remain in service for up to 40 years). The Ministry of Defense cannot stockpile sufficient chips to last the expected service life of the systems it is supporting nor can it be assured that the commercial world will continue to produce this chip. After all, commercial electronics product lines change rapidly and older models are often discontinued.

Concern over shelf life will probably lead the Ministry of Defense to purchase commercial spares on an as-needed basis, assuming they are still being manufactured. Doing so could reduce the ready availability of supplies and significantly raise maintenance costs. The Ministry will be forced to pay commercial market prices for spares and supplies, and no commercial firm will be willing to carry the enormous inventories of equipment that are traditionally maintained by the military. Higher prices for commercial purchases in the marketplace will reflect rates of return based upon scarcity rather than the traditional fixed margins historically written into MoD contracts.

The absence of detailed technical standards, slight production variations among different batches, and uncertainties regarding product performance under a wide range of environmental conditions all raise important defense planning issues as well. Accurate life-cycle cost projections and logistics planning are both very difficult under such conditions.

The Ministry's answer to at least some of these problems is to push for better and longer lasting warranties. The Ministry of Defense now receives 5-year warranties, but it is pushing for life-time warranties. Unfortunately, this is not the panacea it may seem. For one thing, there is no guarantee that the systems integrator will even be in business 5 to 10 years after it delivers a weapons system. In such a case, even with a warranty, the military is still responsible for dealing with the problem if a component fails. Also, the

better and longer lasting the warranty for COTS items, the greater the up-front costs to the Ministry of Defense. Thus, the savings achieved in procurement by using COTS may be eaten away by the price of the warranty.

The adoption of commercial practices like private financing of projects also carries potential downside risks for the Ministry of Defense. As mentioned earlier, the UK's Private Finance Initiative envisions generating off-budget financing of some systems. Part of the enticement to the private sector is the opportunity to export the final product. The danger to the Ministry in this scheme is that the private sector may decide that the foreign market is larger than the domestic one and so will optimize system characteristics to foreign requirements rather than to those of the British MoD.

Leasing also poses potential difficulties, especially if the supplier is providing maintenance and a comprehensive warranty. Employees of private firms may, for instance, refuse to perform field maintenance when the equipment is deployed in high risk peacekeeping operations or war zones. Historical experience suggests that patriotism may overcome such reluctance when there is a clear linkage of the danger to national self-preservation. (For example, shipyard construction workers went to sea on the battleship *Prince of Wales* to finish the fitting out process when it was deployed against the German battleship *Bismarck.*) Absent such clear national imperatives, workers may refuse to go into harm's way. If the military takes over field maintenance responsibility in such situations, the supplier may void the warranties that are predicated on the supplier's own people doing the work.

Alternatively, the government might compel maintenance technicians to service equipment in times of war. Indeed, several of those interviewed mentioned that the law now allows for civilian workers with critical skills to be inducted into military service in time of war. It was not clear from the interviews, however, whether that induction process is voluntary or compulsory. Either way, there are significant downsides from both the commercial and military points of view. Companies may be unwilling to assign their best technicians to military projects if there is a possibility of loosing them to the military. Additionally, companies may have a hard time finding talented workers willing to face the potential risks associated with military service in time of war. It may be an unattractive proposition from the military's point of view as well. For one thing, inducting people to do maintenance somewhat defeats the cost control motives of leasing. Additionally, the military runs considerable risk that it will get less skilled workers during peacetime because the companies and/or the most highly skilled workers will avoid projects that could lead to action in war zones. Finally, provisions to bring civilian

technicians into the military during a war may not cover other kinds of deployments (e.g., peacekeeping actions, humanitarian operations). If not, the military is still faced with the problem of maintaining leased equipment in a manner that will keep warranties in force.

Also, lease providers may be unwilling to accept the additional risks to their property, especially if they ultimately plan to sell it in the secondhand market at the end of the lease. For example, one company refused to honor the warranty for a ground-based radar if it was deployed to Bosnia. Thus, lease providers may have a de facto veto over where the equipment can be deployed or they may insist that the military immediately purchase any leased item deployed in what the lease provider considers a high risk operation. (The perception of risk may differ markedly from the lease provider's and the government's perspectives.)

Even when the Ministry of Defense procures a weapon system that employs COTS, it is difficult to identify any part of the system to which it owns all the rights. Instead, the Ministry usually just has "use rights." This has important implications should the government decide to institute a wide-ranging technology export control regime or to embargo the sale of a product to particular countries. If the military announces in advance its desire to limit foreign sales of dual-use technology in the interest of national security, potential vendors will be less willing to allow it to go into British military systems. Conversely, the Ministry would have to forgo technology export controls in the future.

F. The Applicability of COTS Technology to Military Requirements

It is impossible to estimate with any precision the degree of COTS usage as a percentage of overall British procurement. Study interviewees agree, however, that COTS solutions will never meet 100 percent of the British military's needs. Nevertheless, the British Ministry of Defense is relying ever more heavily on COTS in weapons and ancillary systems over time. Indeed, some of the respondents believed that COTS considerations are now driving the British procurement system. The impressive sample list of British military programs utilizing COTS technology (as described in Appendix A) supports that notion.

As a rule, the farther one gets from the battlefield, the more attractive COTS technologies become: (1) The operating environments are either less extreme or can be controlled without fear of battle damage, (2) Situations are less likely to be life threatening, and (3) Temporary outages are only inconveniences.

As the mission criticality of an individual item lessens or the redundancy to perform that function increases, the more attractive COTS becomes. That is why it is common to have COTS components in tactical aircraft-delivered missile systems but absent from aircraft ejection seats.

There are, however, some natural limits to the applicability and desirability of using COTS to meet military requirements. Where crew safety is a central issue, there is a tendency to disregard COTS solutions. In one case, a company offered to provide 80% of the functionality of an Apache helicopter for only 60% of the cost by using COTS. British military helicopter pilots responded: "Why would we want only 80% of the functionality when flying against a foe with 100% of the functionality?" Similarly, Martin Baker Aerospace claims that their attempts to incorporate COTS components into ejection seats have failed every time. This is primarily due to the extreme envelope within which their seats operate and the life saving function they perform.

The need to confront wide-ranging environmental extremes also limits the desirability of COTS. Wide differences in operating temperatures, for example, is one of the most common limits on using COTS. Traditional military specifications for aircraft engines specify that engine components must be able to operate from minus 55 degrees centigrade to plus 125 degrees centigrade. Both the low and high ends of this range are well beyond the design limits of most commercial components, even though they are typically capable of functioning outside their advertised limits.

Nearness to the forward edge of the battlefield is another natural limitation on the desirability of applying COTS to military missions. Battlefield conditions work against COTS solutions in two ways. Such circumstances produce extremes of shock, vibration, and trauma—all of which are usually well above the stress limits of commercial products. Even if one were to encapsulate commercial components in a "box" to insulate against environmental extremes, shock, and vibration, there is always a strong possibility that the "box" will be breached when the platform sustains battle damage. If that should happen, environmental extremes might ultimately lead to system failure even though the commercial components themselves are unscathed by the original battle damage.

COTS is also not appropriate for areas where reliability is essential and the willingness to take risks is low. In keeping with this precept, the British have consciously excluded COTS from their nuclear weapons program and from their nuclear delivery systems.

Another reason that the British military will never shift totally to COTS is that the commercial market lacks appropriate surrogates in some cases. For example, there are no COTS equivalents to artillery tubes, vehicle armor, and specialized platforms like submarines. Some areas such as microelectronics, however, have numerous surrogates for military-specific products and so encourage substitution by the sheer number of options available.

III. LESSONS AND OVERALL CONCLUSIONS

This study of Britain's experience in exploiting domestic and foreign commercial off-the-shelf technologies to accomplish military missions was undertaken to assist the U.S. Department of Defense as it begins to explore the COTS option. This section distills from British experience a broadly framed set of lessons that DoD might use as it considers COTS alternatives to militarily unique products. It closes with some conclusions about the utility and relevance of COTS technology.

A. Lessons

Lesson 1: Cost drives defense acquisition managers to embrace COTS solutions to military requirements. Thus, it probably is impossible to avoid having some kind COTS-based acquisition strategy in the future. Greatly reduced defense budgets and declining market shares force acquisition officials to make one of two choices: (1) employ some amount of COTS in military programs or (2) make do with much less new equipment. In some cases, the military buys such small amounts of some technologies that industry no longer deems it economically attractive to produce military-specific items. In those cases the choice is COTS or nothing. In other cases, the military may find, for financial reasons, that it can no longer afford to take large risks in developing military-specific products (even if it could find a manufacturer willing to build them).

Lesson 2: Although COTS is a powerful tool for stretching defense resources and for upgrading military capabilities, it is not a panacea. No one interviewed for this study saw COTS as their first choice to meet defense requirements. This is because the use of COTS in military systems forces acquisition managers to make difficult trade-offs and to accept some operational and bureaucratic penalties. Indeed, it often means accepting reduced functionality in the interest of affordability. They would have preferred

to retain the traditional approach of developing and fielding militarily specific technology. They recognize, however, that in most instances this is no longer an option for the reasons discussed above.

Lesson 3: COTS is applicable to a wide range of military problems but is not appropriate or adequate for all military requirements. While it is clear that COTS does not meet all military needs (e.g., crew safety, nuclear weapons reliability), there has (as yet) been no attempt to delineate clear guidelines about what should be considered and what should be rejected. Most attempts to categorize the appropriateness of COTS technology to date have been ad hoc. Therefore, it might be worth developing systematic and comprehensive guidelines as part of a COTS-based acquisition strategy.

Lesson 4: Commercial products often require some modification for use in military systems. In discussing COTS with British defense officials and industry executives, it became clear that what they described as COTS success stories usually involved some degree of product modification to meet military requirements. Often, government people find it impossible to resist "tuning" the project either out of a genuine desire to make the final product better or to justify their continued bureaucratic existence. Whatever the reasons, the British COTS program might better be described as a "non-developmental item" program in U.S. defense parlance.

Lesson 5: Commercial off-the-shelf solutions are more likely to be generated by requirements pull than technology push. In the British case, COTS solutions generally sprang from industry's response to functionally specified requirements rather than from MoD's discovery of an interesting commercial technology that it decided to insert into a particular program. In practice, the distinction between requirements pull and technology push was less clear than it seems since those developing the functional requirements often already knew about existing technologies and wrote the functional specification accordingly.

Lesson 6: COTS can be an important interim solution to a developmental problem. The British found that COTS products were important "gap fillers" when military-specific components did not meet original expectations or when their development took longer than expected. In these situations, the substitution of commercial technologies on an interim basis sometimes allowed weapons and platforms to go into service years before some of their subsystems were ready.

Lesson 7: COTS can reduce acquisition timelines. Commercial purchases can get capabilities into the field more quickly because commercial leading edge technologies

are often well ahead of comparable, existing military technologies in many areas. Even if an existing COTS product needs modification, the commercial world has an advantage since commercial product cycles are typically short—often lasting no more than 18 months at the outside.

Lesson 8: The nature of the military requirements validation and acquisition process can have a major effect on the chances of a COTS solution being adopted. The British acquisition process forces decision makers to routinely consider a COTS alternative in virtually every case. This subtly tilts the process in favor of a COTS outcome.

Lesson 9: How one handles the issue of standards in the requirements generation process is central to any COTS acquisition strategy. The enunciation of functional performance based specifications is more consistent with commercial practices and makes it easier to select a commercial product or technology for a military project. Conversely, detailed technical specifications (especially a rigid military specification standards) make the project less attractive to commercial vendors and make it harder for their products to qualify.

Lesson 10: Flexibility in the acquisition process is essential if a COTS strategy is to succeed. The British acquisition process is built primarily on tradition and custom rather than statute. This gives acquisition managers a good bit of flexibility in the way they write requirements and evaluate proposals. It also permits a good bit of informal contact between government and industry before and during the requirements validation and selection process. Thus, Ministry of Defense officials are frequently aware of commercial technological capabilities very early in the acquisition process. This knowledge works to the advantage of COTS solutions in two ways. Defense officials can write requirements that take advantage of known commercial capabilities. Industry can tailor its response more directly to the Ministry's needs because industry better understands what the Ministry wants in the way of capabilities.

Lesson 11: Flexibility also leads to less control over the outcome of the acquisition process. As the British Ministry of Defense dropped exacting technical specifications in favor of specifications based on functional performance, it ceased to drive the design and development process. Instead, companies increasingly decided the details of the program, and the MoD only made major decisions about the type of capabilities needed, kinds of missions to be performed, and ultimately whether the product was acceptable. In this system, Program Executives moved away from being

"developers" and became more like business executives making cost/effectiveness trade-offs with the emphasis on the first of those two factors. Reliance on commercial products also meant that the Ministry of Defense could prevent manufacturers from making changes over time, even in cases where those changes undercut the military utility of the product.

Lesson 12: Unless the military is willing to pay for adequate performance testing and parts characterization, it may not be able to predict system reliability well. Commercial manufacturers do not always characterize their parts under a wide range of military environments. Thus, it is often impossible to predict if a system will work when needed or under what circumstances it will fail.

Lesson 13: The shelf life of commercial parts and components may be too short under current military logistical practices. The shelf life of commercial parts is usually short, seldom longer than 5 years. This is because commercial vendors do not expect to keep large on-hand inventories and because they expect model changes to make most original items outmoded by the 5-year mark. The military, by contrast, often must support its equipment for several decades. This is a problem because the military can neither warehouse sufficient spares to last the expected lifetime of its systems nor assure that the commercial product will be available for the full life cycle of the military platform it supports.

Lesson 14: Introducing an extensive COTS-based acquisition program is a "long and painful" process. Since the successful implementation of a COTS program is largely a matter of philosophy and attitude, it often requires a cultural revolution in the way people think. Success rests largely on coaxing engineers away from writing their own specifications and convincing acquisition authorities to surrender detailed control of the development process. Resistance is sometimes more than just a matter of clinging tenaciously to old ways of thinking—the change often threatens bureaucratic interests in both government and industry.

B. Overall Conclusions

Virtually everyone agrees that COTS technology is not a panacea. At the same time, there is a consensus among British government and industry people that the use of COTS will continue. Off-the-shelf technologies offer the best hope for modernizing future military capabilities with leading edge technologies in an era of declining defense budgets and limited leverage with the suppliers of militarily relevant technologies.

We therefore believe that the U.S. Department of Defense, like the British Ministry of Defense, will eventually be forced to consider using COTS solutions for an increasingly wide range of military requirements. The shifts in thinking and practices required to exploit fully the opportunities inherent in COTS technology will take time and effort to achieve. As part of this process, the Department will have to decide where to draw the line between COTS acceptability and the continuing need for military-specific solutions to military problems. It will also have to make a number of difficult operational, technological, and bureaucratic trade-offs to strike the right balance between COTS and military-specific solutions. Given the many hurdles it faces in fully implementing a COTS strategy, the Department should begin this process sooner rather than later.

Appendix
SAMPLE OF COTS SYSTEMS IN USE BY THE BRITISH MOD

AIR FORCE

Commercial radio on BAe's HAWK (aircraft trainer)

Commercial computer chips and systems on Eurofighter (combat aircraft)

Commercial acquisition of E-3D Sentry (AWACS aircraft)

Commercial computers on ASTOR (airborne radar)

Open-system architecture on NIMROD upgrade (ASW aircraft)

Commercial components on C-130J (transport aircraft)

Commercial computers for Tornado GR.4 and AV-8B (aircraft upgrade)

Commercial video recorders used for Missile Interface Logical Unit (MILU) for Royal Air Force aircraft

ARMY

Commercial integrated logistics management information system software for Challenger II (main battle tank)

Commercial handheld GPS receivers

Commercial avionics and computers on NH-90 (transport helicopter)

Commercial logistics software and components for the UK's AH-64 Apache (attack helicopter)

Commercial trucks by Land Rover (land transport)

Command and Control Systems (ASH, JOCS, and IARACS)

NAVY

Commercial navigation systems on Type-23 frigates (surface ship)

Commercial computers/displays on Batch 2 Trafalgar Class (attack submarines)

Commercial practices and components to be used for the Common New Generation Frigate (CNGF)

Commercial design practices on Royal Navy ships (i.e., HMS Ocean—amphibious assault ship)

Commercial powerplants on Royal Navy ships

REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 1997	

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
Inserting Commercial Technologies into Military Systems: Lessons from British Experience	DASW01 94C0054 T-AW6-1466
6. AUTHOR(s) Andrew W. Hull, Richard H. White, and David R. Markov	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Institute for Defense Analyses 1801 N. Beauregard Street Alexandria, VA 22311	8. PERFORMING ORGANIZATION REPORT NUMBER IDA Paper D-2104
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of the Deputy Under Secretary of Defense for International and Commercial Programs The Pentagon Washington, D.C. 20301	10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This paper examines robust and long-standing British experience in using commercial off-the-shelf (COTS) technology to satisfy military requirements. It then develops a series of lessons upon which the new commercial insertion program of the U.S. Department of Defense may draw.

14. SUBJECT TERMS	15. NUMBER OF PAGES
COTS, Britain	36
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL